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Hybrid Ventilation in New and Retrofitted Office Buildings

Heiselberg, Per

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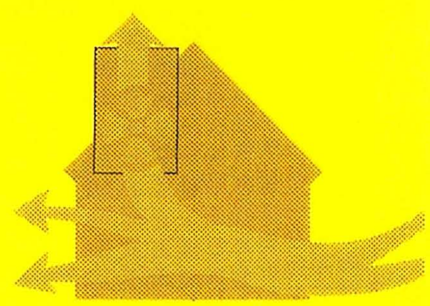

Per Heiselberg

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Per Heiselberg

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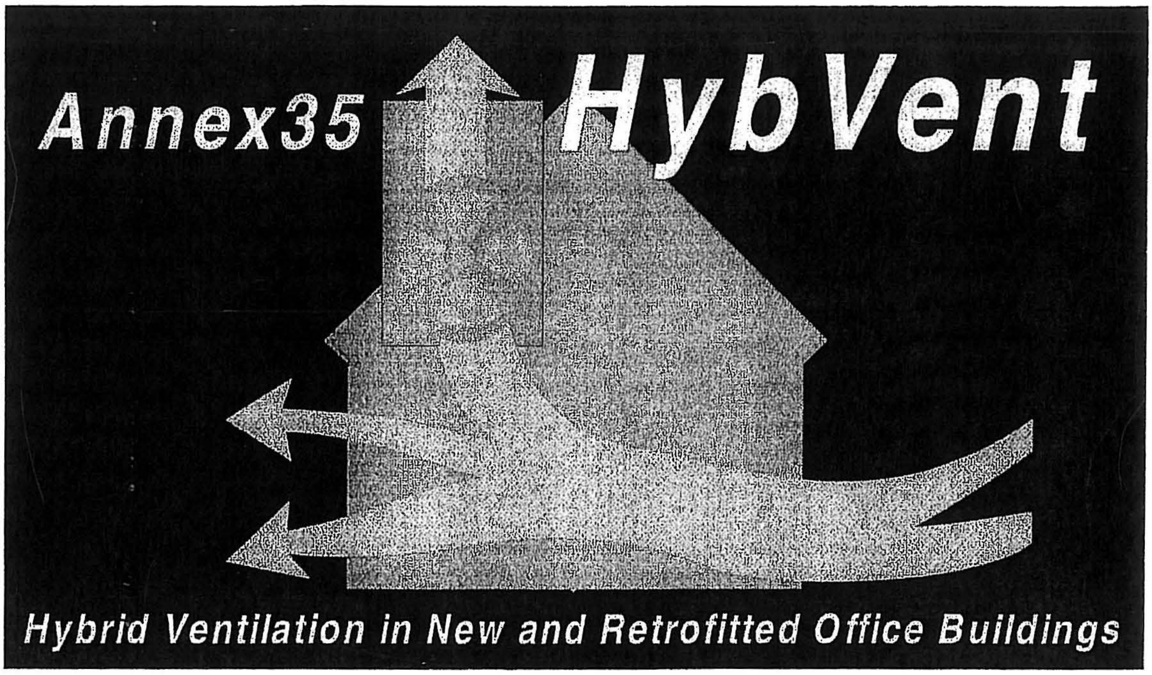

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OPERATING AGENT

PER HEISELBERG

AALBORG UNIVERSITY
Dep. of Building Technology and Structural Engineering
Sohngaardsholmsvej 57
DK-9000 Aalborg
Denmark

Phone: +45 9635 8541
Fax: +45 9814 8243
Email: ph@civil.auc.dk
Homepage: http://hybvent.civil.auc.dk

ANNEX 35
HYBVENT - HYBRID VENTILATION IN NEW AND RETROFITTED OFFICE BUILDINGS.

by

Per Heiselberg, Aalborg University, Aalborg, Denmark

ANNEX DESCRIPTION

The Annex was accepted at the ExCo Meeting in Washington June 1997. The first year, starting August 1, 1997, was a preparatory year. The duration of the Annex will be four years (August 1, 1998 – July 31, 2002) and the project period is divided into three phases - a fact finding phase, a working phase and a reporting phase.

Australia, Canada, Denmark, France, Greece, Italy and Japan has at this stage committed themselves to participate and Belgium, Finland, Germany, Norway, Sweden, The Netherlands, United Kingdom, USA have participated in the preparation phase and will probably join soon.

Background

Today, in the design of new buildings and retrofit of old buildings an integrated approach is used with focus not only on thermal insulation, airtightness and heat recovery but also on optimal use of sustainable technologies as passive solar gains, passive cooling, daylighting and natural ventilation. Buildings are designed to interact with the outdoor environment and they are utilizing the outdoor environment to create an acceptable indoor environment whenever it is beneficial. The extent to which these sustainable technologies can be utilized depends on outdoor climate, building use, building location and design. Under optimum conditions sustainable technologies will be able to satisfy the demands for heat, light and fresh air. In some cases supplementary mechanical systems will be needed and in other cases it will not be possible to use sustainable technologies at all.

Unfortunately, the design of energy-efficient ventilation systems in buildings has often become a question of using either natural or mechanical ventilation. This has prevented a widespread use of sustainable technologies because a certain performance cannot be guaranteed under all conditions with natural ventilation. In fact in the majority of cases a combination of systems would be beneficial depending on outdoor climate, building design, building use and the main purpose of the ventilation system. The development of sustainable ventilation technologies is far behind other sustainable technologies and there is certainly a need for development of innovative hybrid ventilation systems.

The scope of this annex is to obtain better knowledge of the use of hybrid ventilation technologies. The annex will focus on development of control strategies for hybrid ventilation, on development of methods to predict hybrid ventilation performance in office buildings and on development, implementation and demonstration of hybrid ventilation in real buildings.

Definitions

Hybrid ventilation systems can be described as systems providing a comfortable internal environment using different features of both natural ventilation and mechanical systems at different times of the day or season of the year. It is a ventilation system where mechanical and natural forces are combined in a two mode system. The basic philosophy is to maintain a satisfactory indoor environment by alternating between and combining these two modes to avoid the cost, the energy penalty and the consequential environmental effects of year-round air conditioning. The operating mode varies according to the season and within individual days, thus the current mode reflects the external environment and takes maximum advantage of ambient conditions at any point in time. The main difference between conventional ventilation systems and hybrid systems is the fact that the latter are intelligent with control systems that automatically can switch between natural and mechanical mode in order to minimize the energy consumption.

Hybrid ventilation should dependent on building design, internal loads, natural driving forces, outdoor conditions and season fulfil the immediate demands to the indoor environment in the most energy-efficient manner. The control strategies for hybrid ventilation systems in office buildings should maximize the use of ambient energy with an effective balance between the use of advanced automatic control and the opportunity for users of the building to exercise direct control of their environment. The control strategies should also establish the desired air flow rates and air flow patterns at the lowest energy consumption possible.

Objectives

The objectives of Annex 35 are

- to develop control strategies for hybrid ventilation systems in new build and retrofit of office and educational buildings
- to develop methods to predict hybrid ventilation performance in hybrid ventilated buildings
- to promote energy and cost-effective hybrid ventilation systems in office and educational buildings
- to select suitable measurement techniques for diagnostic purposes to be used in buildings ventilated by hybrid ventilation systems

Means

Three subtasks will be carried out in order to reach the objectives:

Subtask A: Development of control strategies for hybrid ventilation

Subtask B: Theoretical and experimental studies of performance of hybrid ventilation. Development of analysis methods for hybrid ventilation

Subtask C: Pilot studies of hybrid ventilation

THEORETICAL AND EXPERIMENTAL STUDIES OF HYBRID VENTILATION PERFORMANCE

Thorough understanding of the hybrid ventilation process is a prerequisite for a successful application of hybrid ventilation, for development of optimum control strategies and for development of analysis methods for hybrid ventilation design. The annex will therefore by theoretical and experimental studies investigate the different elements of the air flow process in hybrid ventilation from air flow around buildings, air flow through openings, air flow in rooms to air flow between rooms in a building. The hybrid ventilation process is very dependent on the outdoor climate as well as the thermal behaviour of the building and therefore, it is essential to take these factors into consideration.

CONTROL STRATEGIES FOR HYBRID VENTILATION

A hybrid ventilation system, which is integrating both natural and mechanical driving forces in the same ventilation system, requires development of new control strategies. These strategies should ensure at any time and for a certain combination of internal loads, outdoor conditions and comfort requirements that the immediate demands to the indoor environment are fulfilled in the most energy efficient manner. As the function of hybrid ventilation is closely related to the use and function of the building a thorough control of hybrid ventilation requires a completely integrated approach where building design, its technical systems (lighting, heating), occupant behaviour, surroundings, climatic and meteorological conditions etc., are taken into consideration.

The participants will as a starting point take a typical case in their own country and climate and by theoretical studies, laboratory experiments and field studies of the performance of different control strategies in a hybrid ventilated building develop the most suitable strategies. The main focus will be on development of strategies for switching between ventilation modes and for combining central automatic and individual manual control.

One of the major tasks will be on development of optimum fuzzy controllers that will enable the implementation of real multicriteria control strategies incorporating expert knowledge and on the development and comparison of smart setting and tuning techniques for these controllers. This will enable a rational operation and improved performance of the fuzzy controllers and is a necessary condition for implementing complex control techniques.

DEVELOPMENT OF ANALYSIS METHODS

Suitable analysis methods as we know them for mechanical systems are not available for hybrid ventilation systems. Valid methods would give architects and engineers the necessary confidence in system performance, which in many cases, is the decisive factor for choice of system design.

As the hybrid ventilation process and the thermal behaviour of the building are linked the development of analysis methods for hybrid ventilation must take both aspects into consideration at the same time and include efficient iteration schemes. This is the case for all types of analysis methods from simple analytical methods, zonal and multizone methods to detailed CFD analysis methods. The subtask will deal with methods on different levels, but a major focus will be on combining thermal simulation models with existing multizone air flow models. In this way the thermal dynamics of the building can be taken into account and this will improve the prediction of the performance of hybrid ventilation considerably. The combined model will be the most important design tool for hybrid ventilation.

The second major development is a new probabilistic analysis method that makes it possible to evaluate indoor climate, energy consumption and certainty of the design solution based on the whole operation period. The method should be able to predict the probability that demands of energy consumption, indoor climate and air flow rates are met in hybrid ventilated buildings. The method will be developed, by combining available physical models of the phenomena involved with stochastic models and will be useful in the early design phase.

PILOT STUDIES OF HYBRID VENTILATION

Pilot studies in different countries are used to implement hybrid ventilation systems and demonstrate their performance. The pilot studies are monitored to collect data on performance (IAQ, thermal comfort and energy consumption) and to evaluate corresponding control strategies and analysis methods. The pilot studies include both retrofitted and new build designs and highlight similarities and differences in climatic issues (including seasonal differences), institutional and cultural issues (developers and occupants), and technology transfer issues. The pilot studies concentrate on success stories of hybrid ventilation but also critically highlight problematic cases.

Buildings with hybrid ventilation often include other sustainable technologies like daylightning, passive cooling, passive solar gains etc, and an integrated approach is used in the design of the building and its technical systems. The following shows two examples of pilot studies included in Annex 35.

Grong Scholl Building, Grong, Norway

A new wing of the Grong primary school were finished in August 1998. It is a single floor building of 1000 m^2 with efficient use of daylight, control of artificial lighting, CO_2 controlled hybrid ventilation, passive solar heating and night cooling.

An air inlet tower is located outside the building. The air is brought into the building through an underground duct to a distribution chamber below the central circulation spine. The air is distributed in the classrooms by low-velocity diffuser at floor level and exhausted at ceiling level. The exhaust air is extracted through an exhaust chamber above the circulation spine, and out through a centrally located tower providing a stack effect. Heat recovery is provided by a run-around system. Fans are installed both at the supply and the exhaust side to provide additional driving force, especially when heat recovery and heating is necessary and cannot be bypassed.

The ventilation is controlled by a BEMS system with CO_2 and temperature sensors in each classroom.

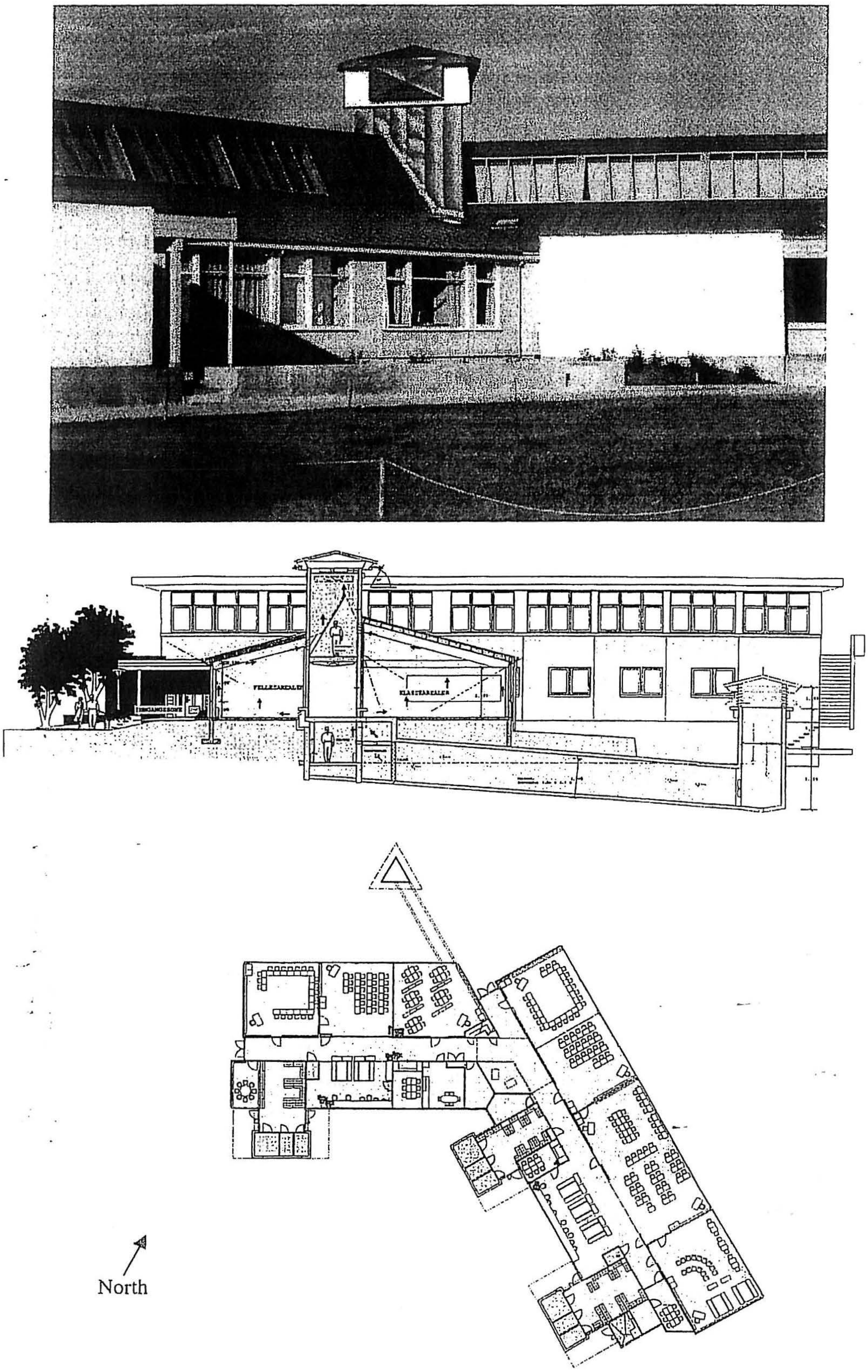

Figure 1. Grong primary school, Grong, Norway

B&O Headquarters, Struer, Denmark

B&O headquarters is three new buildings with a total $5100m^2$ of offices and exhibition area. It was finished in August 1998. Meeting rooms, canteen, kitchen etc. are mechanically ventilated. The offices and exhibition area are designed with efficient use of daylight, control of artificial lighting, CO_2 controlled hybrid ventilation, passive solar heating and night cooling. The open plan office building of about $1000m^2$ has three floors, a width of 7.5m and a length of 45m.

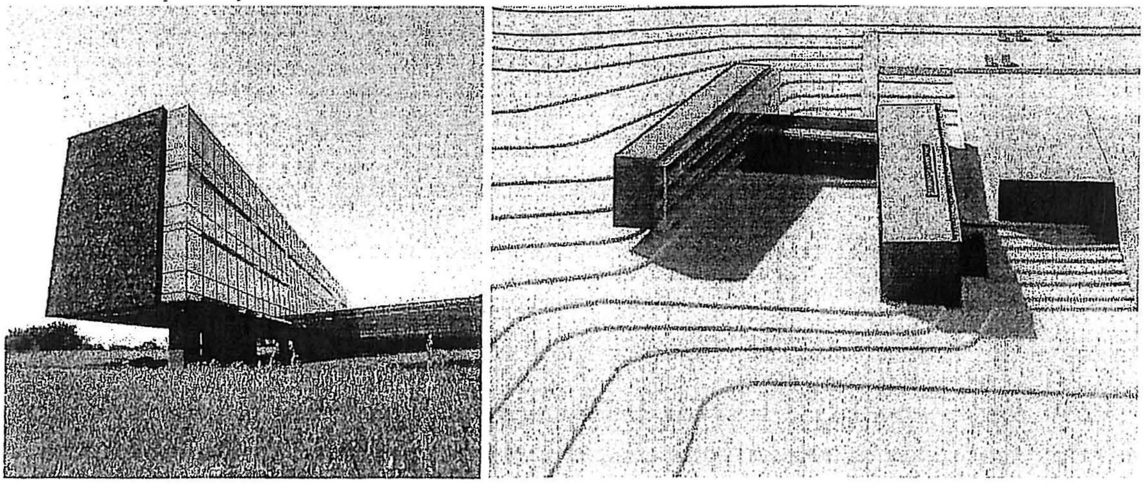

Figure 2. B&O Headquarters, Struer, Denmark.

The north facade is a fully glazed facade for extensive use of daylight with narrow openings at floor level for air intake. Intakes are provided with ribbed pipes to preheat incoming air. The south facade has manually openable windows for summer ventilation. Air flow through the open office plan and is extracted through two stairways. The stairways are equipped with propeller fans to provide additional driving force if necessary.

The ventilation openings are controlled by a BEMS system and the control strategy is based on time schedule and room temperature and CO_2 levels. Facade openings are controlled to get approximately the same amount of inflow through all openings. In the south facade windows are manually controlled by occupants.

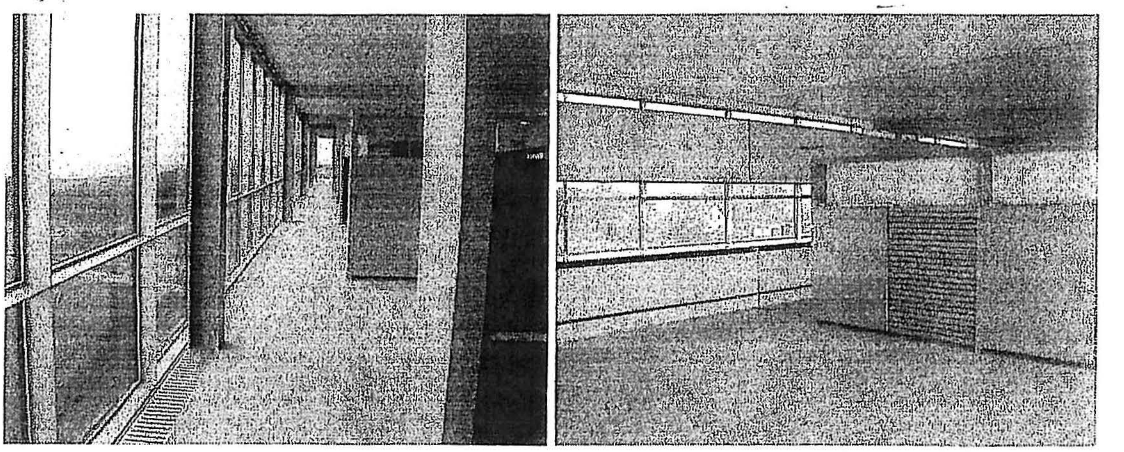

Figure 3. Inside view of north and south facade.

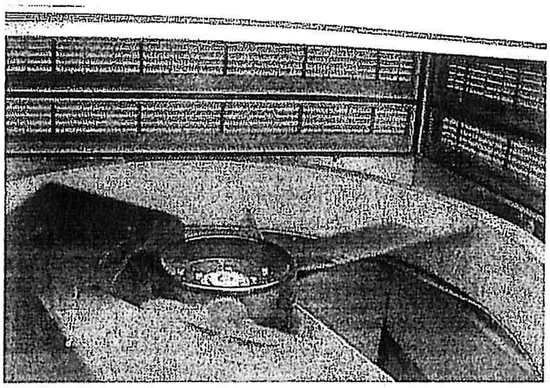 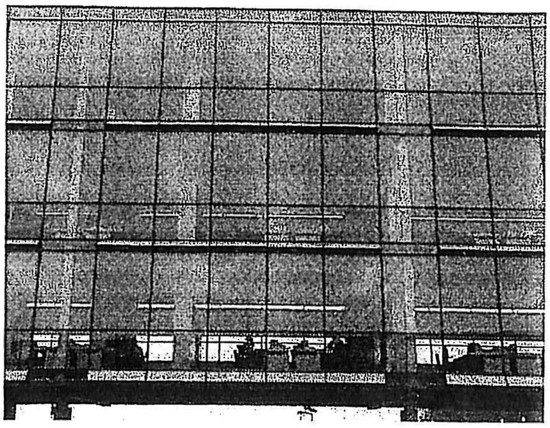

Figure 4. Top of stairway with propeller fan and close-up of inlet openings in south facade.

STATE-OF-THE-ART REVIEW

The work in the annex at this stage is concentrating on providing a state-of-the-art review of hybrid ventilation. A survey of existing buildings and systems is performed in the participating countries together with a survey of commercially available components. All information will be available through a MS Access database. Selected material, summaries and conclusions are included in the state-of-the-art report. A survey of building codes and standards and their impact on application of hybrid ventilation is performed and summaries and conclusions are also included in the state-of-the-art report. The state-of-the-art review will identify weaknesses and lack of knowledge in system performance, components, control strategies and design methods, and identify and prioritise research needs.

ANNEX 35 WEB – SITE

All information about the annex is available on the Annex 35 Web-site (http://hybvent.civil.auc.dk). This web site will gradually grow through the working period of the annex and beside description of the annex, the web–site will include papers and publications, information about pilot studies and monitoring programmes as well as measurement and analysis results.

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Dept. of Building Technology and Structural Engineering
Aalborg University, October 1999
Sohngaardsholmsvej 57, DK-9000 Aalborg, Denmark
Phone: +45 9635 8080 Fax: +45 9814 8243
http://iee.civil.auc.dk